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RESPONSE OF RICE VARIETY SARO 5 (TXD 306) TO P, Zn and Cu FROM DIFFERENT PHOSPHORUS SOURCES FERTILIZERS IN MBASA VILLAGE, KILOMBERO DISTRICT, TANZANIA

Fatuma Gharibu Nassoro
Research Officer I, Department of Seed Certification, Tanzania Official Seed Certification Institute
P.O BOX 1056, MOROGORO, TANZANIA.
Godson Sosthenes Basinda
Agricultural Officer II, Department of Seed Certification, Tanzania Official Seed Certification Institute
P.O BOX 1056, MOROGORO, TANZANIA.
Frank Maxmillian Faida
Agricultural Officer II, Department of Seed Certification, Tanzania Official Seed Certification Institute
P.O BOX 1056, MOROGORO, TANZANIA.
Eliud Theonest Ngimbwa
Researcher, Department of Administration, National Arts Council and Finance
P.O BOX 4029, DAR ES SALAAM, TANZANIA.

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ABSTRACT

The study is aimed at evaluating the response of rice variety fertilizer SARO (TXD 306) to P, Zn and Cu from different P sources fertilizers in selected rice growing areas in Kilombero district. Soil fertility analysis was conducted to determine physical and chemical properties of soil for suitability of rice growing. A screen house and field experiments were conducted to assess the response of rice variety SARO (TXD 306) to P, Zn and Cu from fertilizers sources (MPR, Minjingu mazao and DAP) and different levels of Zn and Cu using soils from Mbasa village. The results showed that the soils are acidic (pH 5.2 to 5.9), with low P (1.48 to 9.83 mg kg-1), low total N (0.11 to 0.22 mg kg-1), exchangeable Ca (< 10 cmol kg-1) and base saturation (2.38 to 5.54 %). The experimental results showed significant higher grain yield in all P sources (> 29.7 g pot-1) at ($P<0.05$) than the control (N alone) treatment (15.5 g pot-1) in P deficient Mbasa soil. Minjingu mazao did not differ ($P < 0.05$) from other P sources in terms of grain yield in soils under screen house conditions. Application of 2.5 mg kg-1 Zn in combination with DAP gave highest grain yields (39.23 g pot-1) but was statistically similar to Minjingu mazao.

Under field condition in Mbasa Vijana 1 soil, all P sources resulted in significantly higher grain yield of 5.92 t ha-1 in Minjingu fertilizers and 6.94 t ha-1 in DAP than control 4.42 t ha-1. Application of Zn and Cu increased grain yield to a maximum of 6.38 in Minjingu and 7.51 t ha-1 in DAP with all rate of Zn and 1.1 mgkg-1 Cu treatments. Minjingu mazao fertilizer was comparable to other P sources and has the ability to supply P as DAP fertilizer.

Keywords: Rice; MPR; Minjingu mazao; DAP; yield components; soil fertility.

1. INTRODUCTION

Rice production in Kilombero valley in Morogoro region, Tanzania accounting for more than 80 per cent cultivated land within the valley (Isinika et al.,2021). In Tanzania, rice (*Oryza sativa* L.) is the second widely cultivated cereal food crop after maize. The crop is grown in three agro-ecosystem namely rainfed lowland (74%), rainfed upland (20%) and irrigated lowland (6%) (Mghase et al 2010). It is a major source of income, food and employment across the country,

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and particularly rural areas (Joachim, 2018). Small scale rice farming is characterized by many small holder farmers, cultivating small farms (0.5 to 10 acres) (RLDC, 2011). Kilombero district is one of the potential areas in rice production but has a record of low rice productivity. Recent studies, reported rice yield to range between 0.5 and 2.0 t/ha under rainfed lowlands of Kilombero district (Asheri et al., 2017). The low paddy production and grain yield obtained by smallholder farmers is due to low soil fertility. This contributed to low or no use of mineral fertilizers or organic manures. This led to nutrients mining that induce deficiencies of macro-and micro-nutrients. Research shows that only 4 to 6.7% rice producers use inorganic fertilizers, and mostly only nitrogen (N) and phosphorus (P) containing fertilizers. In Tanzania, the deficiencies of N, P, K, Zn and S nutrients in rice production areas reported by several researches work showed that P levels in Kilombero soils is low and limit rice production. Studies found 60% and 67% respectively, of studied soils under paddy production areas in Kilombero district, have insufficient P for high rice yields (Asheri et al.,2016). Also, recent study supports the hypothesis that S and Zn are low and emerging as limiting factors for rice production in soils of Kilombero. Also, the deficiencies of N, P, K and Zn were reported in eastern Same district where rice has been cultivated for over 100 years (Amur and Semu, 2006). Zinc deficiency was reported in Igunga and Nzega districts in Tabora region (Semoka *et al*., 1996; Msolla, 1991). This trend of nutrient deficiencies in rice cropping systems requires effective sources of fertilizers to supply the respective nutrients. Thus, replenishing deficient nutrients in the soil is necessary if increased rice production is to be realized. This suggests that application of phosphate fertilizers alone is not suffice, hence, its necessary to include S and Zn fertilizers to optimize rice yields.

Under this circumstance it was important to evaluate the response of rice variety SARO (TXD306) from P sources fertilizers namely Minjingu mazao fertilizer (10% N, 8.8% P, 5% S, 0.5% Zn, 0.5% Cu and 0.1% B), Minjingu hyperphosphate (MPR) and Di-ammonium phosphate (DAP). The supply of Zn and Cu from Minjingu mazao depends on the standard rate of P application, which is 1.1 kg Zn ha^{-1} and 1.1 kg Cu ha^{-1} if P is applied at 20 kg P ha^{-1}. Thus, it was important to conduct soil fertility status to evaluate the deficiencies of nutrients and to determine the optimum levels with respect to these nutrients. Low soil fertility and imbalanced nutrients application are important and their improvements may boost rice production for majority of Tanzanian farmers particularly those of Kilombero district.

2. METHODOLOGY

2.1 Description of study area

The study was conducted in Mbasa village which is one of the major rice producing villages in Kilombero District. Kilombero is a major rice producing valley, supplying about 9% of all rice produced in Tanzania (Kato, 2007). The valley is located between S 8° 15’ 0” and E 36° 25’ 0.12” extending from east to southwest from below the Udzungwa Mountain. The annual precipitation in the Kilombero valley is between 1,000 and 2,000 mm from November to April. A transect walk reconnaissance survey was conducted in Mbasa village and soil samples for soil fertility status were collected. Geographical coordinates of villages sites studied were collected using Global Position System (GPS) (Garmin Trex legend HCx, 2007) and are shown in Appendix 1.

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2.2 Soil sampling and sample preparation for general fertility status

Reconnaissance soil fertility survey was conducted during which, soil samples were collected at a depth of 0-20 cm from major rice growing village (Mbasa village) in Kilombero District. Six composite soil samples were collected in each site, where a minimum of ten soil sub-samples obtained randomly in a relatively uniform area of about 0.5 ha using an auger. The soil subsamples were then mixed thoroughly to constitute six composite samples. The composite samples were transported to SUA, air- dried ground to pass through a 2-mm sieve for laboratory analysis.

2.2.1 Soil sampling for pot experiment

Screen house experiments was conducted at Sokoine University of Agriculture (SUA), Morogoro. The aim of the pot experiment was to study the deficiency symptoms and response of rice to nutrients from P fertilizers in this soil under controlled environment. The representative bulk sample was collected from Mbasa Vijana 1 site. The soils were sampled at 20-cm depth to give 150 kg soil. The bulk sample was air dried and sieved to pass through an 8 mm sieve for pot experiment.

2.3 Fertilizers and seeds

The fertilizers used for this study were Di-amonium phosphate (DAP) 20.1% P, Minjingu phosphate rock 13% P, and Minjingu mazao 8.4% P as sources of P. The source of N was UREA (46% N), Zinc source was zinc sulphate ($ZnSO_4.7H_2O$) with 23 % Zn while Copper source was copper sulphate ($CuSO_4.5H_2O$) with 39.6% Cu and seeds of SARO 5 (TXD 306) rice variety was chosen because the variety is popular to farmers in Kilombero district.

2.4 Soil analysis

Soil pH was analyzed in a 1: 2.5 soil: water suspension ratio by using a pH meter. Extractable P was determined according to the Bray I method [18] following colour development by phospho-molybdate blue method. Exchangeable cations (Ca, Mg, K and Na) were determined from ammonium acetate (NH4OAc) leachate. Zinc and Cu were determined by Diethylene triamine pentaacetic acid- (DTPA) (DTPA) method and its concentration in the filtrate was determined by atomic absorption spectrophotometry using appropriate standards. Extractable Sulphur was extracted by Calcium orthophosphate and BaCl2 turbidity method was used for determination of S concentration.

2.5 Pot experiment

2.5.1 Experimental design

Sreenhouse experiment was conducted at Sokoine University of Agriculture (SUA), Morogoro for 134 days using soils from Mbasa village. Four-kg soil from were weighed separately into four-litre pot to obtain 45 pots with Mbasa soil. The pots were arranged into three blocks in the screen house based on the NE to SW orientation. The treatments were combinations of different sources of P, one source of N, and different levels of Zn and Cu. The sources of P were Minjingu phosphate (13% P), Di ammonium phosphate (DAP) (20.1% P), and Minjingu mazao (8.8 % P) all applied at the rate of 80 mg P pot^{-1} and N as urea was applied at the rate of 500 mg N kg^{-1} soil. The levels of Zn were 0.0, 1.1, 2.5, 5.0 and 10.0 mg Zn kg^{-1} soil, while levels of Cu were 0.0, 1.1, 2.5 and 5.0 mg Cu kg^{-1} soil where by fifteen treatments were used and randomly assigned into each pot in each block. Zinc and copper sulphates and all P sources were applied before planting by thoroughly mixing the fertilizers with the soil in each pot to ensure uniform distribution. Nitrogen fertilizer was applied as top-dressing fertilizers in three splits. The control treatment was supplied with nitrogen only. Therefore, the experimental design was Randomized Complete Block Design with three replications in each soil.

2.5.2 Management of pot experiment

The soil in each pot was moisten and left for 24 hours before sowing and the seeds were also soaked for 24 hours before sowing. Sowing of rice seeds was done in triangular shape in a pot and five seeds were planted per hole, to give 15 rice seeds per pot. Thinning was done 14 days after sowing (DAS) and three plants were maintained per pot. Moisture content of the soils in the pots was determined by the Salvage method (Appendix 2) and was maintained at 90% ± 10% of field capacity by timely application of distilled water to replenish moisture lost due to evapotranspiration for the first 21 days. The addition of 570 mls distilled water was enough to moisten dry soils to 90 % of field capacity. First split of N fertilizer was applied 21 days after planting and the second split was done 21 days after the first split and the third split was also done 21 days after the second split.

2.6 Field experiment

A field experiment was conducted at Mbasa village for 120 days and was divided into blocks based on the slope of the field. Each block had 19 plots and space between blocks was 1 m. Treatments consisted of different combinations of three P fertilizer sources, five Zn rates and four Cu rates to give 18 treatments (Appendix 4). The treatments were randomly assigned in plots within blocks. The experimental unit was a plot of size 2m x 5m, the space to separate one plot to another was 0.5 m. Nitrogen and phosphorus were applied at the rate of 120 kg N ha^{-1} as UREA in two splits and 20 kg P ha^{-1} from MPR, DAP and Minjingu mazao. The micronutrients were applied at the rate of 0.0, 1.1, 2.5, 5.0 and 10.0 mg Zn ha^{-1} and 0.0, 1.1, 2.5 and 5.0 mg Cu ha^{-1} as Zinc and Copper sulphate, respectively. Except N, all the nutrients were applied by broadcasting followed by thoroughly mixing with the soil in the plots before sowing. The first split of N was applied 14 days after sowing rice (variety SARO 5-TXD 306) in 20 by 20 line spacing. The second split of N was applied 21 days after first split. Flooding was done after applying the first split of N. Continuous flooding was maintained until 14 days before harvesting.

2.7 Plant sampling and sample preparations for dry matter yield

Rice dry matter yield was estimated to determine treatment effect on growth of rice in screen house and for the field experiment. The two rice shoots in the screen house experiment were harvested from each pot at booting stage (80 DAS) by cutting at 1 cm above the soil surface. Two rice plant shoots from each plot were randomly selected and cut at 1 cm above the soil surface from each experimental unit at booting stage (78 DAS). Both field and screen house rice shoots were dried in the oven at 65 ˚C to constant weight, and weighed to obtain dry matter yield (DM).

2.8 Harvesting and determination of grain yield

The grain yield both at field and screen house pot experiment was obtained by harvesting panicles at harvesting stage by hand. In the field experiment, the three mid rows were harvested, while in the pot experiment the panicles from two rice plants per pot were harvested. The

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harvested rice was then threshed, sun dried and winnowed to remove unfilled grains. The grains were sun-dried and weighed. The grain yield in tonnes ha^{-1} and g pot^{-1} was calculated under field and screenhouse experiments, respectively.

2.9 Data Analysis

All data collected were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 15. The treatment means were ranked and separated using Duncan Multiple Range Test (DMRT) at 5 % significance level. The coefficient of variation (CV) in percentage was recorded.

3. RESULTS AND DISCUSSION

3.1. Soil physical properties for rice production

The textural classes of the soil samples tested in Mbasa village ranged from coarse textured (sand clay loamy) to moderately fine (loamy) soils (Table 1). According to Landon (1991) medium to heavy textured soils are favourable for rice production because of good water holding capacity and good nutrient supply. Some parts of Mbasa village had higher percentage sand of >70 (Table 1) and this could result in high losses of water and nutrients through leaching. Also, study done by Mghase et al., 2010 found sandy clay loam in Ulanga and Kyela soils in rice production areas. Soil texture is an important soil characteristic, particularly for irrigation and rice production. It influences water holding capacity, root ability, and retention of plant nutrients in soils (Joel and Mrema, 2017). Therefore, recycling of organic amendments (organic manures and or crop residues) might be needed to reduce water and nutrients losses.

3.2 Soil pH

The soil pH ranged from 5.2 to 5.9 (Table 1), which are grouped as low to medium pH according to Landon (1991). Van Breeman (1980) reported that the pH range of 4.5 to 6.5 is satisfactory for rice production. Mghase et al., 2010 found medium acidic in Matombo and Korogwe soils in rice production areas. The optimum soil pH for rice plants is 5.5 to 6.5 under dry conditions (non-irrigated rice production system) and 5.5 to 7.2 under flooded conditions (Prosper and Jerome, 2017). Therefore, the pH range of soils of Mbasa village is suitable for rice production under flooded conditions.

3.3 Organic carbon

The organic carbon obtained in the soils tested ranged from 0.40% to 1.85% (Table 1). These values are rated as very low to medium, according to Baize (1993), where <0.60 % as very low, 0.6 to 1.25 % as low, 1.26 to 2.50 % as medium, 2.51 to 3.50 % as high and >3.50 % as very high. This translates low organic matter content in soil which contribute to poor soil structure, low soil nutrients content, retention and water retention. Organic matter in soils influence both the physical, chemical and biological properties of soils, such as soil structure, water retention, nutrient contents and retention and micro-biological life and activities in soils. Also, study done by Prosper and Mrema, (2017) found low organic matter in rice producing village in Lekitatu, Arusha. These levels are similar to those obtained in selected soils for rice in Same district (Amur, 2003). Also, other studies done in some selected paddy growing areas of Morogoro, Tabora, Coast and Mbeya regions showed low C content (Mzee, 2001). The low percentage organic carbon contents translate to low organic matter content in soils. Therefore, to improve optimum rice production organic soil amendments like manures or crop residues have to be applied.

3.4 Total nitrogen

The percentage total nitrogen in the soils ranged from 0.11 to 0.22 (Table 1). Landon (1991) rated total N in soils as <0.1 as very low, 0.1 to 0.2 as low, 0.2 to 0.5 as medium, and 0.5 to 1.0 as high and >1.0 as very high. The total N of soils tested in this study rated as low. Amur (2003) also reported total N below the critical value of 0.15 % in some selected paddy production areas in Same district. Joel and Mrema (2017) found low Total N in Lekitatu rice growing village, Arusha. Low total N might also be due to leaching because the soil texture of these sites is sand clay to sandy clay loam (Table 1), long term cultivation with limited use of organic amendments such as manures, and crop residues. Therefore, to supplement the deficient N, the use of nitrogen fertilizer is necessary in paddy production in this area.

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Table 1. Physical and chemical properties of the soils selected in Mbasa village rice growing areas

		Soil separates %								CEC & Exchangeable bases (cmol (+) kg^{-1})					
Location	pH (H_2O)	Clay	Silt	Sand	TC	% OC	% N	P mg/kg^{-1}	S mg/kg^{-1}	CEC	Ca	Mg	Na	K	% BS
Mbasa-Viwanja 70	5.50	11.40	10.20	78.40	*SL*	0.40	0.11	2.08	0.27	10.80	0.72	0.21	0.30	0.18	2.91
Mbasa-Kapolo 1	5.28	23.40	12.20	64.40	*SCL*	1.21	0.17	9.83	1.15	10.00	1.28	0.33	0.39	0.16	3.55
Mbasa-Kapolo 2	5.20	27.40	20.20	52.40	*SCL*	1.85	0.22	6.25	1.48	16.40	3.24	0.98	0.40	0.15	5.54
Mbasa-Kasikana	5.81	11.40	12.20	76.40	*SL*	0.53	0.13	1.48	0.71	10.40	1.03	0.20	0.31	0.12	2.65
Mbasa Vijana 1 (expt.site)	5.97	9.40	10.20	80.40	*LS*	0.77	0.11	3.58	0.22	8.40	1.03	0.24	0.34	0.15	3.35
Mbasa Vijana 2 (field)	5.81	11.40	10.20	78.40	*SL*	0.77	0.12	2.69	1.97	9.60	0.83	0.23	0.33	0.09	2.38

Note: SCL=Sandy clay loam; CL=Clay loam; CL=Clay loam
BS=Base saturation

3.5 Available phosphorus

The available P in the soils tested ranged from 1.48 to 9.83 mg P kg^{-1} (Table 1). Dobermann and Fairhust (2006) rated available P level in rice growing soils <7 mg P kg^{-1} as low, 7 to 20 mg P kg^{-1} as medium and >20 mg P kg^{-1} as high. Five sites of the study area had low available P, while one site had medium level of available P. Phosphorus is important in plants because it plays a critical role in physiological and biochemical processes such as photosynthesis, respiration, N fixation, root development, maturation, flowering, fruiting, and seed production (Johnston and Steen, 2000). Study done by (Joel et al., 2016) found low level of available P in Ndungu Irrigation Scheme Same District. The soils tested in the study had low P fertility status and hence are likely to respond to P fertilizers such as DAP, MPR and Minjingu mazao. Therefore, P fertilizers application is necessary to correct P deficient soils.

3.6 Cation exchange capacity

The cation exchange capacity (CEC) of the tested soils ranged from 9.60 to 10.80 cmol $_{(+)}$ kg^{-1}(Table 2). The values ranged from low to medium Landon, 1991 categorized CEC levels as follows: <5 cmol$_{(+)}$ kg^{-1} as very low, 5 to 15 cmol$_{(+)}$ kg^{-1} as low, 15 to 25 cmol$_{(+)}$ kg^{-1} as medium, 25 to 40 cmol$_{(+)}$ kg^{-1} as high and >40 cmol$_{(+)}$ kg^{-1} as very high. The tested soils had low CEC. The results obtained could be attributed to low soil organic matter content due to long term cultivation without addition of manures, nature of soil parent materials and type of clay minerals present in the soils. Also, study done by (Kajiru et al.,2014) in rice growing Maswa District, Shinyanga found to had low CEC. The CEC is the measure of the potential fertility of the soil and possibly the response to fertilizer application Landon (1991).

3.7 Exchangeable bases

3.7.1 Calcium (Ca)

The exchangeable Ca in the soils of the study area ranged from 0.72 to 3.24 cmol $_{(+)}$ kg^{-1} **(**Table1). Landon (1991) categorized exchangeable Ca levels as follows: <2.0 cmol $_{(+)}$ kg^{-1} as very low, 2.0 to 5.0 cmol $_{(+)}$ kg^{-1} as low, 5.1 to 10.0 cmol $_{(+)}$ kg^{-1} as medium, 10.1 to 20.0 cmol $_{(+)}$ kg^{-1} as high and >20.0 cmol $_{(+)}$ kg^{-1} as very high. Based on this categorization, the status of Ca is very low to low levels. This could be due to low pH, low organic matter, low CEC, leaching, long cultivation without nutrients addition, and nature of parent materials where the soils developed (Kitundu, 2001). Mghase et al.,2010 found low Ca levels in soils of Kyela rice growing areas. Minjingu phosphate rock fertilizers rich in CaO (25% CaO) have potential benefit as a source of Ca, in addition to P, in Kilombero soils.

3.7.2 Magnesium (Mg)

The exchangeable Mg in the soil tested ranged from 0.21 to 0.24 cmol $_{(+)}$ kg^{-1} (Table 1). Kitundu (2001) categorized exchangeable Mg levels as follows: <0.3 cmol $_{(+)}$ kg^{-1} as very low, 0.3 to 1.0 cmol $_{(+)}$ kg^{-1} as low, 1.1 to 3.0 cmol $_{(+)}$ kg^{-1} as medium, 3.1 to 6.0 cmol $_{(+)}$ kg^{-1} as high and >6.0 cmol $_{(+)}$ kg^{-1} as very high. According to this categorization, the soils under this study had very low to low exchangeable Mg. Therefore, soils of Mbasa areas need Mg application. Also, Mghase et al.,2010 found low level of Mg in soils of Kyela rice producing areas.

3.7.3 Sodium (Na)

The exchangeable Na in tested soils ranged from 0.30 to 0.40 0.56 Cmol $_{(+)}$ kg^{-1} (Table 1). Ngerageza (1999) categorized exchangeable Na <1 cmol $_{(+)}$ kg^{-1} as low and >1 cmol $_{(+)}$ kg^{-1} as high. Thus, the soils under study recorded low in exchangeable Na. Amur (2003) reported low exchangeable Na in Ndungu irrigation scheme of Same, Kilimanjaro region, Tanzania. The low exchangeable Na would provide good environment for rice growth, because when high percentage of CEC is occupied by Na^{+}, the soil aggregate disperses and lead the soil to be impermeable to water. Therefore, exchangeable Na will not limit rice production in Mbasa village.

3.7.4 Potassium (K)

The exchangeable K in the studied soils ranged from 0.09 to 0.18 cmol (+) kg-1 as given in Table 1. Landon (1991) categorized the exchangeable K in soils <0.2 cmol (+) kg-1 as very low, 0.2 to 0.4 cmol (+) kg-1 as low, 0.41 to 1.2 cmol (+) kg-1 as medium, and 1.21 to 2.00 cmol (+) kg-1 as high and >2.00 cmol (+) kg-1 as very high. All soils studied had very low exchangeable K. Mghase et al., 2010 obtained vey low to low K level in soil of Kyela, Matombo, Korogwe rice growing areas. Low exchangeable K might be due to leaching and low CEC, and none re-cycling of crop residues, hence poor K retention capacity of the soils. Therefore, application of potash fertilizers is necessary for optimum rice production.

3.8 Base saturation

The base saturation (BS) in soils tested ranged from 2.38 to 5.54% 12.06 (Table 1). According to Landon (1991), base saturation is the indication of soil fertility status, where BS of <20 % indicates low, 20 to 60% indicates medium, and >60 % indicates high general fertility. Based on this categorization, all the soils in this study had low BS hence, are of poor soil fertility. Therefore, there is a need for enhancement of fertilizer use in this area to replenish the nutrients and general maintenance of fertility status before the situation becomes worse.

4. Micronutrient

4.1 Zinc

The amount of Zn extracted from the tested soils ranged from 0.02 to 1.94 mg Zn kg^{-1} soil (Table 2). Dobermann and Fairhust (2006) categorized DTPA extractable Zn levels of < 0.8 mg kg^{-1} as low in rice growing soils. Three sites observed to had low level of Zn while two sites had Zn level above the critical range. Mbasa-Kasikana (0.02 mg Zn kg^{-1}) and Mbasa Vijana1 (0.04 mg Zn kg^{-1}) had low level of Zn. These results show that the soils of Mbasa area had no serious Zn deficiency. However, those few areas detected with Zn deficiencies need attention. Other studies done by Mzee (2001) reported low extractable Zn levels at two sites in Lupilo and Michenga villages in Tanzania. The low levels of Zn in some selected rice growing areas of Igunga and Nzega were also reported by Msolla (1991). Therefore, application of zinc fertilizers is necessary for optimum rice production.

Table 1. Chemical properties (micronutrients) of the soils selected in Mbasa village rice growing areas

Location	Zn	Cu
	(mg kg^{-1})	
Mbasa-Viwanja 70	BD	0.16
Mbasa-Kapolo 1	0.94	1.88
Mbasa-Bwawani	1.94	3.73
Mbasa-Kasikana	0.02	0.20
Mbasa-Kapolo 2	1.79	3.45
Mbasa Vijana 1-(exp.site)	0.04	0.24
Mbasa Vijana 2-(bulk)	BD	0.12

***BD=below detection**

4.2 Copper

The DTPA extractable Cu in tested soils ranged from 0.12 to 3.73 mg Cu kg^{-1} (Table 2). Dobermann and Fairhust (2006) categorized DTPA extractable Cu levels of 0.2 to 0.3 mg kg^{-1} soil as adequate in rice growing soils. The soils tested in some parts of Mbasa village had sufficient amounts of available Cu for rice production while two sites (Mbasa Vijana 2 and Mbasa Viwanja 70) had deficient Cu levels. Therefore, the soils in some parts of Mbasa village may not supply adequate amounts of copper for plant growth.

5. Response of P sources on rice growth under screen house condition in Mbasa Vijana 2 soils.

The response of rice to P applied to the Mbasa Vijana 2 soil under screen house is shown in Table 3. The control gave the lowest number of tillers i.e., 7 tillers $hill^{-1}$ in Mbasa Vijana soils. Phosphorus application from all sources resulted in significantly greater number of tillers than control. The lowest number of tillers in the control indicated that P is the most limiting nutrient for tillering during rice growth. Application of DAP as P sources gave highest number of tillers

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(18 tillers hill^{-1}), followed by Mijingu mazao (15 tillers hill^{-1}) and lastly Minjingu (10 tillers hill^{-1}) in Mbasa soil. (Table 3).

Dry matter yields due to application of different P fertilizers followed the same trend as tillers. All sources of P gave significantly greater dry matter yield than the control. In Mbasa soil, DAP gave the highest DM of 25.98 g pot^{-1}, which was significantly greater than Minjingu (17.55 g pot^{-1}) and Minjingu mazao (16.90 g pot^{-1}) Table 3. The response of N and P in terms of tillering and dry matter yield was higher in Mbasa Vijana 2 soil. This indicates that N and P were more limiting nutrients in Mbasa Vijana 2 soil. The soil test results in Table 1 show that the total N content of Mbasa Vijana 2 soil was 0.12 % which was rated as being low while P content was 2.69 mg kg^{-1} which was also low. The differences in initial soil P also explain fast response of rice to DAP, a high P releasing fertilizer due to high solubility in a highly P deficient of Mbasa Vijana 2 soil compared with slow P release Minjingu fertilizers. The use of slow-release P fertilizers like Minjingu based fertilizers in acid soils is expected to build up P in soils, and hence to have similar responses as DAP in the subsequent years.

The lowest number of tillers and DM yield in the control treatment indicates that P is the crucial nutrients for maximum tillers and accumulation of dry matter during crop growth compared with N alone. P induces good tillering, ensures normal grain development and improves food value of rice (Jones *et al*., 1982). Phosphorus is important for plant growth and promotes root development, tillering, early flowering and performs other functions like metabolic activities, particularly in synthesis of protein (Tabar, 2012). Also, it should be noted that the productivity of rice is greatly determined by the number of products rather than total number of tillers (Hasanuzzaman, 2010). Thus, these results show that the Minjingu mazao performance is comparable to other P sources in enhancing tillering and dry matter accumulation in rice.

Table 2.Response of P, Zn and Cu on growth and yield of rice grown in Mbasa Vijana 2 soils under screen house condition

Treatment	Number of Tillers (Tillers hill^{-1})	Dry matter yield (g pot^{-1})	Grain yield (g pot^{-1})
	Mbasa	Mbasa	Mbasa
$N_{500}P_0Zn_0Cu_0$	7e	4.35c	15.53 c
$N_{500}P_{80DAP}Zn_0Cu_0$	18a	25.98a	34.66 ab
$N_{500}P_{80DAP}Zn_{1.1}Cu_0$	15ab	23.61a	37.83a
$N_{500}P_{80DAP}Zn_{2.5}Cu_0$	17a	25.44a	39.23a
$N_{500}P_{80DAP}Zn_5Cu_0$	15b	24.72a	38.75a
$N_{500}P_{80DAP}Zn_{1.1}Cu_{1.1}$	13bcd	24.97a	33.78ab
$N_{500}P_{80DAP}Zn_{2.5}Cu_{2.5}$	12bcd	20.64ab	34.63ab
$N_{500}P_{80DAP}Zn_5Cu_5$	17a	23.70a	33.68ab
$N_{500}P_{80MP}Zn_0Cu_0$	10d	17.55b	29.72 b
$N_{500}P_{80MP}Zn_{1.1}Cu_0$	12bcd	18.39b	34.16ab
$N_{500}P_{80MP}Zn2._{5}Cu_0$	12bcd	18.34b	29.16b
$N_{500}P_{80MP}Zn_5Cu_0$	11d	17.71b	38.17a
$N_{500}P_{80Mazao}Zn_{1.1}Cu_{1.1}$	15abc	16.90b	34.03ab
$N_{500}P_{80Mazao}Zn_{2.5}Cu_{2.5}$	13bcd	20.66ab	32.76ab
$N_{500}P_{80Mazao}Zn_5Cu_5$	13bcd	16.94b	36.11ab

CV	13.5	14.1	3.1

*Number in the subscript indicates the rate of nutrient applied in mg pot^{-1}; nd – not determined; DAP di-ammonium phosphate; MP – minjingu hyper-phosphate; Mazao –minjingu mazao.
* Means in the column with the same letter (s) are not significantly different (*P<0.05*) according to Duncan's New Multiple Range Test.

5.1 Response of Zn and Cu on rice tillering and dry matter yield under screen house condition in Mbasa Vijana 2

The response of added Zn and Cu on number of tillers and dry matter yield is shown in Table 3. Treatments with combination of N and P gave higher (P<0.05) tillers and dry matter yield in Mbasa Vijana 2 soils over the control. Application of N, P, and Zn gave higher tillers number and dry matter yield (17 tillers hill^{-1}) and (25.44 g pot^{-1}) in Mbasa Vijana 2 soil in the treatment combination of N, P $_{(DAP)}$, and Zn over the control. This indicated that there was slightly response to Zn in Mbasa Vijana 2 soil Application of Zn in addition to N and P gave comparable number of tillers with Minjingu mazao treatment but significantly lower than DAP treatment over the control (Table 3). The soil of Mbasa Vijana 2 had DTPA extractable Zn below detection (BD) in Table 2, suggesting that the level of Zn was below the detection limit of the equipment used. According to data obtained, there was no response of rice to Cu in Mbasa Vijana 2 soil although the soil data suggested possibility of Cu deficiency (0.2 mg Cu kg^{-1}) as shown in Table 2. Therefore, the optimum Cu level in Mbasa Vijana 2 soil need to be further evaluated.

5.2 Response of application of Phosphorus from three sources on grain yields under screen house condition using Mbasa Vijana 2 soil.

The response of P applied to the Mbasa soil on rice grain yield under screen house is shown in Table 3. The grain yields in all treatments with P from all sources were significantly (*P*<0.05) greater than the control in Mbasa soil. In Mbasa soil there was no significant (*P*<0.05) difference in grain yield between DAP (34.66 g pot $^{-1}$) and Minjingu mazao (34.03 g pot^{-1}) but not in MP treatment (29.72 g pot^{-1}) over the control. Therefore, there was no significant (*P*<0.05) difference in P response on grain yield in DAP and Minjingu mazao. On the other hand, the higher grain yields due to P application in Mbasa soil were expected due to low P in this soil than Mang'ula soil.

5.3 Effects of Zinc and Copper application on grain yields under screenhouse conditions using Mbasa Vijana 2

Rice grain yield due to Zn and Cu application in Mbasa Vijana 2 soil is shown in Table 3. The highest grain yield in Mbasa soil was obtained in the DAP treatment in combination with Zn at 2.5 kg ha^{-1} (39.23 g pot^{-1}), which did not differ significantly with MP in combination with Zn at 5 kg ha^{-1} (38.17 g pot^{-1}) and Minjingu mazao in combination with Zn and Cu (36.11 g pot^{-1}). The results indicated response to Zn in terms of increase in grain yield in Mbasa soils regardless of sources of P. Muthukumararaja and Sriramachandrasekharan (2012) reported the highest grain yield (37.53 g pot^{-1}) at 5 mg Zn kg^{-1}, which was about 10% greater than control. Higher yield due to zinc fertilization is attributed to its involvement in many metallic enzyme systems, regulatory functions and auxin production, enhanced synthesis of carbohydrates and their transport to the site of grain production (Muthukumaraja and Sriramachandrasekharan, 2012).

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6.0 Response of application of P from three P sources on grain yield under field conditions at Mbasa Vijana 1 site.

The effect of P application in Mbasa Vijana 1 soil on rice grain yield under filed condition is shown in Figure 1a and 1b. The grains yield among treatments with P from all sources were significantly (*P<0.05*) difference than the control in Mbasa Vijan 1 soil as shown in Figure 1a and 1b. There was no significant difference (*P*<0.05) on grain yield between Minjingu mazao and MPR (both with 5.92 t ha^{-1}) in Figure 1b, respectively but not in the DAP treatment (6.94 t ha^{-1}) in Figure 1a. The control gave the lowest grain yield than all treatments (4.42 t ha^{-1}) as shown in Figure 1a and 1b. The addition of N and P gave significantly (*P*<0.05) higher grain yield in DAP treatment (6.94 t ha^{-1}) over the control as shown in Figure 1a. This shows that N and P are limiting nutrients in Mbasa Vijana 1 site as shown in Table 1.

The result indicated that P increased grain yield over the control. A study done in Bangladesh reported that application of 26 kg P ha^{-1} increased paddy yield by 2.5 t ha^{-1} in Kharif season and 5.7 t ha^{-1} in Rabi season. Also, application of 72 kg P_2O_5 ha^{-1}(31.4 kg P ha^{-1}) produced the highest grain yield (7.23 t ha^{-1}), and resulted in yield increase of 45% over the control (Alam *et al*. 2009). Therefore, P is important in grain yield as it helps in grain filling in panicles and also size of grains. Higher grain yield due to P application in Mbasa Vijana 1 soil was expected due to low P content in this soil as shown in Table 1.

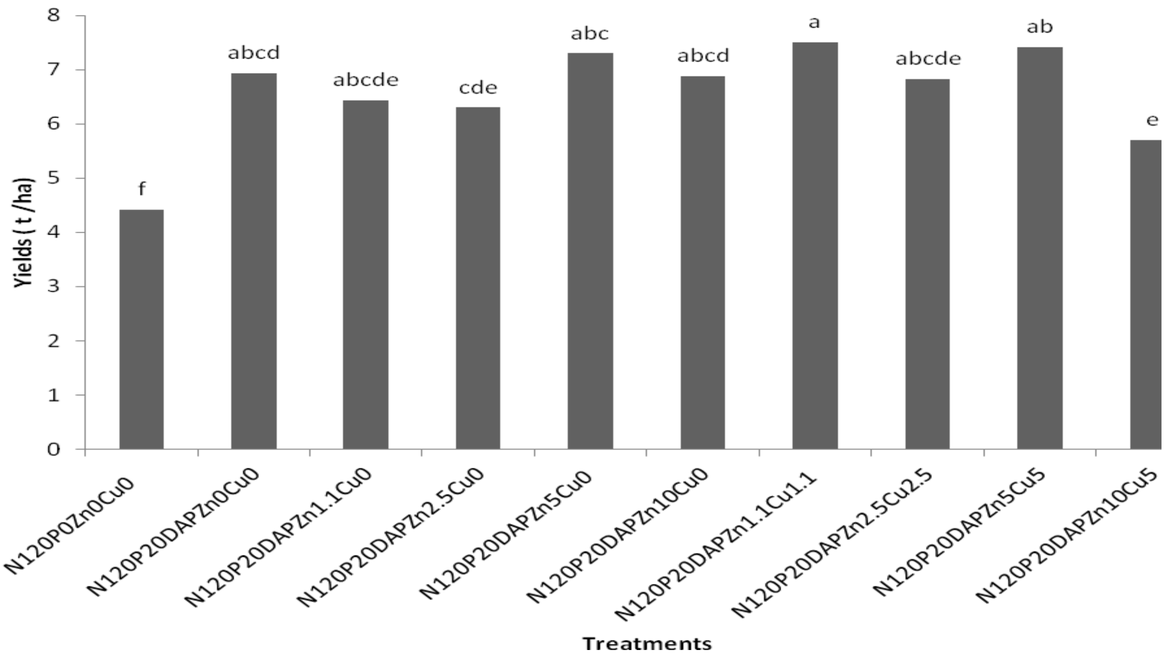

Figure 1a. Effects of P, Zn and Cu applied on grain yield under field conditions at Mbasa Vijana 1 site.

Number in the subscript indicates the rate of nutrient applied in mg kg-1; DAP- di-ammonium phosphate

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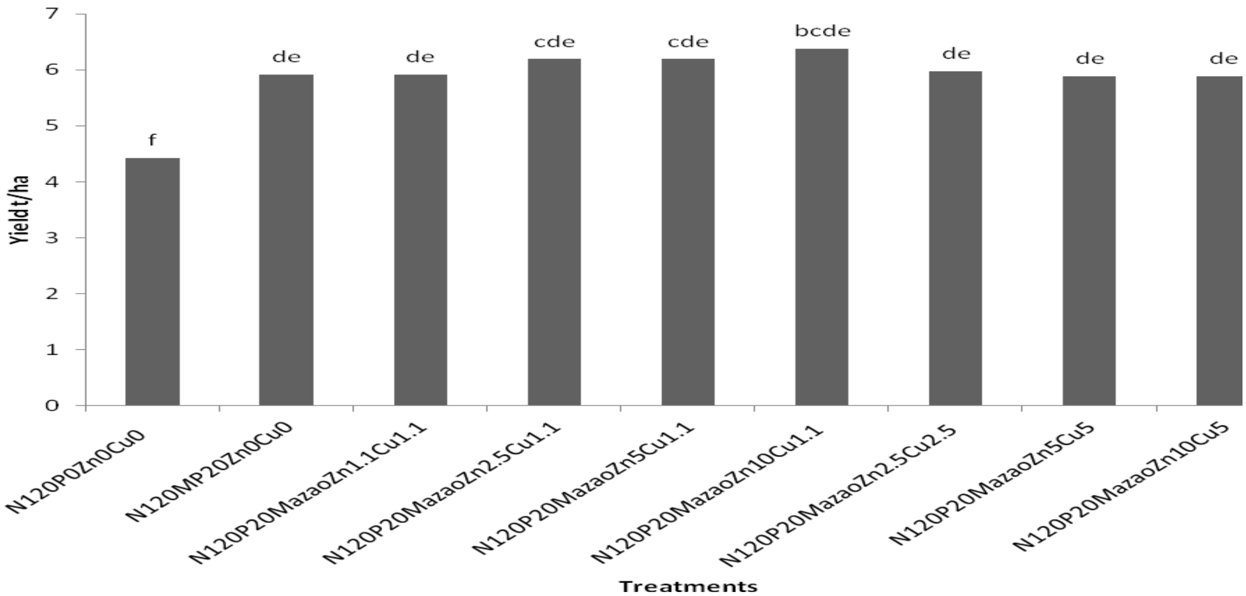

Figure 1b. Effects of P, Zn and Cu applied on grain yield under field conditions at Mbasa Vijana 1 site.

Number in the subscript indicates the rate of nutrient applied in mg pot-1; MP – minjingu hyper-phosphate; Mazao –minjingu mazao.

6.2 Effect of Zn and Cu on rice grain yield under field condition in Mbasa Vijana 1 soil.

Rice grain yield due to Zn and Cu application in Mbasa Vijana 1 soil is shown in Figure 1a and 1b. The highest grain yield (7.51 t ha^{-1}) in Mbasa Vijana 1 soil was obtained in DAP treatment with Zn and Cu at 1.1 mg kg^{-1}, which differ significantly from DAP alone and Mijningu mazao treatment as shown in Figure 1a and 1b. The results indicate a slight response of Zn in terms of increase in grain yield in Mbasa Vijana 1 soil regardless of sources of P. However, there was no response of rice to Cu application. The drop of grain yield was obtained in DAP treatment with highest Zn (10 mg Zn kg^{-1}) and Cu (5 mg Cu kg^{-1}) applied as shown in Figure 1a. This could imply that these high rates of Zn and Cu might not be required for optimum rice production in this soil.

7.CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusion

Based on the result of this study, it can be concluded that:

a) The results showed that the soils surveyed are acidic (pH 5.2 to 5.9), low P (1.48 to 9.83 mg kg^{-1}), low total N (0.11 to 0.22 mg $kg^{-1)}$, and exchangeable Ca (<10 cmol(+) kg^{-1}) , exchangeable Mg and base saturation (2.38 to 5.54 %).
b) The physical and chemical properties of soils show that the soils studied are suitable for use of Minjingu mazao and other P fertilizers derived from Minjingu rock phosphate because the soil will allow solubility of Minjingu phosphate. This is because the soils are acidic, low P and exchangeable Ca.

c) Application of N and P generally increased rice dry matter yield, tillers and grains in both screen house and field experiment. Addition of N, P and Zn together further increased rice dry matter and grains yield.
d) Application of N alone in P deficient soils delays rice maturity. Also, this shows the importance of P nutrient in rice plants for tillering and grains filling, hence early maturity. Therefore, N and P together are crucial elements for optimum maturity and rice growth.
e) Generally, all P sources in screen house and field condition, showed increase in yield significantly over the control. Therefore, MPR and Minjingu mazao has ability to supply P although DAP treatments performed better.

8. Recommendations

Based on observations and results obtained from the study the following are recommended:

a) The amount of Zn contained in Minjingu mazao is not sufficient to correct Zn deficiency soil, so Minjingu mazao can be applied three consecutive seasons to see the impact of Zn but this should be verified by research.
b) Minjingu rock phosphate (MPR) fertilizers will be suitable in this area as the low pH will help in its solubilization and the phosphate rock will gradually raise soil pH.
c) The use of macro and micronutrients fertilizers should be insisted to farmers than macronutrients alone where there are deficiencies.

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APPENDICES

Appendix 1: Areas of Kilombero district from where the experimental soils were collected

VILLAGE	COORDINATES	DESCRIPTION
Mbasa sheme	S 08^0.09798 E 036^0.71284	Bulk sample was taken; the area showed the signs of nutrients deficiency in phosphorus and nitrogen in rice plants. The crop grown: rice mainly by transplanting). The dominant soil is
Mbasa- Kapolo 1	S 080.09995 E 036^0.71066	Near swampy area. The dominant soil is clay. Crop grown: rice mainly by transplanting.
Mbasa – Viwanja 70	S 08^0.10410 E 036^0.71347	Sandy loam soils- alluvial brought by river during rains. Easy and friable. Crop grown is rice: mainly by transplanting.
Mbasa- Kapolo 2	S 080.09949 E 036^0.71006	Localized heavy clay soils near swampy area. The other area is dominated by sandy clay loam Crop grown: rice mainly by transplanting.
Mbasa- Kasikana	S 080.09697 E 036^0.71707	The dominant soil is sandy loam. Crop grown: rice mainly by transplanting.
Mbasa- Kapolo	S 08^0. E 036^0	The dominant soil is sandy clay loam. Easy to work with and friable. Good rice yield is 20-25 bags /acre. Crop grown: rice mainly by transplanting.